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College of Agriculture and Rural Transformation

Department of Plant Sciences

Effect of Plant Population on Yield and Yield Components of Chickpea (*Cicer arietinum L.)* at Tseda woreda, North Gondar,Ethiopia

MSc.Research Thesis

By

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DEDICATION

I dedicate this Thesis to University of Gondar who gave me the opportunity to sponsor my research expense under the university “Mega Project”.

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BIOGRAPHICAL SKETCH

The author, Berhanu Tsegaye, was born on March 16, 1983 in Debre tabour town, Amhara Region from his father Mr Tsegaye Tarko and his mother Mrs. Tagegne mekonnon. He attended his Elementary at Amoragdel Missionary School and Secondary School at Bole Senior Secondary School Addiss Abeba. After passing the Ethiopian School Leaving Certificate Examination, he joined Haramaya University in 2004 and graduated with BSc degree in plant science June, 2007. After graduation, he worked at Debub Omo Zone as agricultural expert and as Quarantine Expert, Environmental science expert, Urban Agriculture Expert at West Gojjam zone Jabitenan Woreda and now working as Inventory Controller at Ethiopian Commodity Exchange Enterprise at Gondar Branch. He joined the School of Graduate Studies at Gondar University in July, 2015 to pursue a study leading to the Degree of Master of Science in Agronomy.

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ACRONYMS

ANOVA	Analysis of Variance
CSA	Central Statistical Agency
DZARC	Debrezeit Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research
FDRE	Federal Democratic Republic of Ethiopia
GLM	Generalized Linear Model
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
RCBD	Randomized Complete Block Design
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
MT	Metric tons
SAS	Statistical Analysis System

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Effect of Plant Population on Yield and Yield Components of Chickpea (*Cicer arietinum L.)* at Tseda woreda, North Gondar, Ethiopia

ABSTRACT

A field experiment was conducted at college of agriculture and rural transformation experimental site Tseda, during 2017 cropping season to determine the effect of different inter row (20, 30, 40, 50cm) and intra row spacing (5, 10, 15 cm) on growth parameters, yield components and yield of Habru chickpea. The experimental design was randomized complete block design in factorial arrangement with three replications. There was highly significant (P<0.01) effect of inter- row spacing's on days to 50% flowering, days to 90% maturity, number of seeds per pod, hundred seed weight. The 50 cm inter row spacing gave the highest number of seeds per pod (1.23) and hundred seed weight (31.34 g). Number of seeds per pod and hundred seed weight were significantly increased as the intra row spacing increased. The interaction effect of inter row and intra row spacing was significant on plant height, number of primary branches, number of pods per plant, number of seeds per pod, above ground dry biomass, grain yield and harvest index. For all of the inter row spacing's, the number of primary branches was increased as the intra row spacing increased. There was a progressive increase of number of pods per plant as the inter- and intra-row spacing increased while the highest above ground dry biomass (6555 kg ha^{-1}) was recorded at 20×5 cm spacing. For all of the inter row spacing, the harvest index was increased as the intra row spacing increased. The 20 cm inter- by 5cm intra- row spacing gave the highest grain yield (3036kg ha^{-1}) while the lowest grain yield (1400 kg ha^{-1}) was recorded from 50 cm ×15 cm spacing. Grain yield of 20cm × 15cm and 30cm × 10cm spacing combinations showed statistical parity. From this study it can be concluded that 20 cm×5 cm spacing can be recommended for the site.

Key words: 'Kabuli' type chickpea, inter-row spacing, intra-row spacing,

1 INTRODUCTION

Chickpea (*Cicer arientinum L.*) is a cool season annual pulse crop that belongs to the Leguminosae family. It is an ancient crop that is believed to have been first grown in Turkey 7500 years ago (Oplinger *et al.,* 1990). It is the third most important pulse crop after dry beans and dry pea (Singh and Saxena, 1999). Chickpea is grown in wide range of environments comprising about 44 countries in tropical, subtropical, and temperate regions of the world (Muehlbauer and Tulle, 1997)

In Ethiopia, chickpea is widely grown across the country and serves as a multi-purpose crop (Shiferaw B and Haile Mariam T, 2007). First, it fixes atmospheric nitrogen in soils and thus improves soil fertility and saves fertilizer costs in subsequent crops. Second, it improves more intensive and productive use of land, particularly in areas where land is scarce and the crop can be grown as a second crop using residual moisture. Third, it reduces malnutrition and improves human health especially for the poor who cannot afford livestock products. It is an excellent source of protein, fiber, complex carbohydrates, vitamins, and minerals. Fourth, the growing demand in both the domestic and export markets provides a source of cash for smallholder producers. Fifth, it increases livestock productivity as the residue is rich in digestible crude protein content compared to cereals.

Two types of chickpea are cultivated in the world: Desi and the Kabuli types. The Desi types have smaller seeds with angular appearance, sharp edges and varying colors. The Kabuli type produces large round seeds with white or pale cream or yellow color. Of the two groups, the Desi types are more widely cultivated in Ethiopia. However, currently, there is considerable interest in the Kabuli type for export. Chickpea is generally grown in drought prone areas, and derives most of its water requirements from residual stored soil moisture rather than from rainfall, chickpea yields tend to trail those of cereals and other legumes cultivated in more favorable areas (Joshi *et al.,* 2001; Bekele *et al.,* 2004).

Inspire of efforts made in the past to increase its production, the productivity of the crop in Ethiopia under farmers condition is low (1.73 t ha$^{-1)}$ (CSA, 2012) as compared to its potential yield of the crop under improved management conditions (3.5 t ha^{-1}). Good yields even from the high yielding varieties cannot be achieved without the adoption of improved package of technology. Seeding densities, appropriate adjustment between the rows, and judicious use of fertilizer, timely sowing and irrigation play a remarkable role in increasing the yield of crops.

One of the main reasons of low yield of *C. arietinum* is improper plant population. Either too low or high Plant population beyond a certain limit often adversely affects the crop yield. Number of plants per unit area influences plant size, yield components and ultimately the seed yield (Beech and Leach, 1989). The use of high plant density in chickpea production decreases soil water evaporation early in the growing season when plant canopy closure is low. In contrast, low plant density may allow weeds to develop more aggressively and limit crop yield potential. Plants grown at lower plant density are usually shorter and branchy, which increases losses during combine harvest (Singh and Saxena, 1999). Moreover, plant spacing in the field is also very important to facilitate aeration and light penetration in to plant canopy for optimizing the rate of photosynthesis. There is very little information available on the relative contribution of various plant spacing towards yield and yield components and also their interaction. Plant population is a key component of the productivity of chickpea. The yield of chickpea can be improved by planting of optimum density of chickpea cultivars. Optimum density is one of the factors that have effect on yield, but there are some studies that have shown that density does not have a significant effect on yield of cicer and some studies have shown that density have a significant effect on yield of chickpea. Panwar *et al.,* 1980 reported row spacing of 45 cm increased chickpea yield compared to 30 and 50 cm spacing's while Parihar , 1996 indicated that row spacing had no significant effect on seed yield. Hussain *et al.*, 1998 reported that higher plant population increased the seed yield compared to a lower plant population due to more number of seeds plant^{-1}, branches plant^{-1} and 100-seed-weight. Whereas harvest index, seed pod^{-1} and plant height were not influenced statistically by plant population. Sarwar, 1998 reported that row spacing's significantly influenced the number of branches plant^{-1} and number of seeds plant^{-1}, whereas plant height, number of seeds pod^{-1}, 100-seed- weight, biological yield, seed yield, straw yield and harvest index were not affected significantly by row spacing's. Khan *et al*., 2001 concluded that narrow row spacing of 30 cm produced significantly maximum yield than that of wider row spacing of 70 cm. But Barary *et al.,* 2002 observed the effect of row and plant spacing on seed yield was non-significant. However, 30 cm inter-row spacing and 10 cm intra-row spacing is used for both' Kabuli' and 'Desi 'types of chickpea in Ethiopia (FDRE, 2010). In addition limited research work has been done on the interaction effects of various agronomic practices such as variety with plant spacing in the country. There is also no site and variety specific recommendation on the plant population density of chickpea cultivars in Ethiopia rather; there is blanket recommendation of 30×10 cm spacing.

Therefore, the objective of this study was;

- to determine the effect of inter- and intra- row spacing on yield and yield components of chickpea.

2 LITRATURE REVIEW

2.1 Botany and Development of Chickpea

Chickpea seeds have a seed coat, two cotyledons, and an embryo. The seed coat consists of two layers, the outer testa and the inner tegmen, and a hilum. The hilum is the point of attachment of the seed to the pod. There is a minute opening above the hilum called the micropyle, and a ridge formed by the funicle called the raphe. The embryo consists of an axis and two fleshy cotyledons. The pointed end of the axis is the radicle and the feathery end is plumule.

Chickpea seeds germinate at an optimum temperature varying within (28-33°C) and proper moisture level in about 5-6 days. Germination begins with the absorption of moisture and swelling of the seed. The radicle emerges first followed by the plumule. The portion of the axis above the cotyledon called the epicotyl, elongates and pushes the plumule upward. The growth of the plumule produces an erect shoot and leaves, and the radicle grows to produce the roots. The first true leaf has 2 or 3 pairs of leaflets plus a terminal one. The plumular shoot and lateral branches grow continuously to develop into a plant (Cubero, 1987).

Chickpea plants have a strong taproot system with 3 or 4 rows of lateral roots. The parenchymatous tissues of the root are rich in starch. All the peripheral tissues disappear at plant maturity, and are substituted by a layer of cork (Cubero, 1987). The roots grow 1.5-2.0 m deep and bear Rhizobium nodules. They are of the carotenoid type, branched with laterally flattened ramifications, sometimes forming a fanlike lobe (Corby,1981).

The chickpea stem is erect, branched, viscous, hairy, terete, herbaceous, green, and solid. The branches are usually quadrangular, ribbed, and green. There are primary, secondary, and tertiary branches (Cubero, 1987). Primary branches arise from the ground level as they develop from the plumular shoot as well as the lateral branches of the seedling. They are thick, strong, and woody, and may range from one to eight in number. Secondary branches develop at buds located on the primary branches. They are less vigorous than the primary branches. Their number ranges from 2 to 12. The number of secondary branches determines the total number of leaves, and hence, the total photosynthetic area. Tertiary branches arise from the secondary branches.

The primary branches form an angle with a vertical axis, ranging from almost a right angle (prostrate habit) to an acute angle (erect). Generally, stems are incurved at the top, forming a spreading canopy.

Chickpea leaves are petiolate, compound, and uniimparipinnate (pseudoimparipinnate). Some lines (genotypes) have simple leaves. The rachis is 3-7 cm long with grooves on its upper surface. Each rachis supports 10-15 leaflets each with a small pedicel. The leaflets do not end at the true terminal position (the central vein continuing the rachis) but at the sub terminal position (the central vein oblique to the rachis). This indicates the presence of two terminal leaflet buds, one of them being aborted or transformed into a mucro or foliar shoot which is sometimes quite large (Cubero ,1987).

The leaflets are 8-17 mm long and 5-14 mm wide, opposite or alternate with a terminal leaflet. They are serrated, the teeth covering about two-thirds of the foliar blade. The shape of the leaflets is obovate to elliptical with the basal and top portions cuneate or rounded. Leaves are pubescent.

The solitary flowers are borne in an axillary raceme. Sometimes there are 2 or 3 flowers on the same node. Such flowers possess both a peduncle and a pedicel. The racemose peduncle is 6-30 mm in length. At flowering, the floral and racemal portions of the peduncle form a straight line, giving the appearance that the flowers are placed on the leafy axil by a single peduncle. After fecundation the raceme is incurved. The bracts are 1-5 mm in length.

2.2 Environmental Requirements of Chickpea

Chickpea is traditionally grown in the northern hemisphere, mostly at relatively high elevations in India and Ethiopia. However, most of the Desi type chickpea is grown between 20^0 N and 30^oN while Kabuli type is grown above 30^oN (Saxena and Singh, 1987). These environmental conditions give significance difference in photoperiod, temperature and precipitation, all of which have a profound effect on growth and development (Saxena and

Singh, 1987). The crop is a quantitative long-day plant which needs a moderately high temperature for its normal growth. A daily temperature fluctuation with narrow amplitude is also required by the crop. Chickpea grows best on heavy clay soils and in a rough seed-bed and it is moderately tolerant to drought conditions (Van der Maesen, 1972). Cool nights, moderate relative humidity, evenly distributed rainfall and well drained seed-beds are conducive to the crop and are considered as the ecological optimum of the crop for its normal growth and development (Van der Maesen, 1972).

In major chickpea growing regions of the world, the average maximum temperature ranges from 21 to 29^{o}C during the day and from 15 to 25^{o}C during the night. The crop needs daily mean temperature of above 15^{o}C to allow fertilization of flowers and pod setting (Trang and Giddens, 1980). Considerable differences in ambient and/or soil temperature requirements have also been noticed among cultivars of chickpea. There is also a considerable variation among cultivars for soil temperature requirement for germination, but generally it should exceed 5^{0}C, and preferably be above 15^{o}C. For high yields, bright sunshine is required; cloudy weather, particularly if accompanied by high humidity, reduces flowering and seed setting. Chickpeas are normally grown in areas with an annual rainfall of about 650-750 mm although they can be grown successfully in areas with a rainfall of about 1000 mm/annum. Chickpeas can be grown on a wide range of soil types provided that the drainage is good, and they cannot withstand water-logging. For optimum results, clay loams are required. In general, chickpea are moderately sensitive to photoperiod and the vegetative period is shortened in long days, but short days (9 hours) do not prevent flowering (Kay, 1979).

2.3 Chickpea Area, Production and Yield Trends in the World

Chickpea is the most important food legume crop in the world grown on about 11 million ha worldwide with a total production of 9 million tons in 2006-08 (Akibode and Maredial, 2011). South Asia is by far the largest producer of chickpea (76%) in the world with a share of more than 80% of area harvested. The share of developing world in total area and production of chickpea is 95% and 93%, respectively. The region of Middle East and North

Africa is the second most important region for chickpea area and production followed by Sub-Saharan Africa. The South East Asia and Latin American and Caribbean region as have more than 100 thousand ha of chickpea, but are relatively insignificant players from the global perspective.

The regions that have seen a substantial increase in area harvested under chickpea in the last 14 years include the South East Asia region (by 67%) and the developed countries (rest of the world) (by 48%). Over the same period, the area also increased by 18% in Sub Saharan Africa and marginally in South Asia (less than 1%). Both the Latin American and Caribbean region and Middle East and North Africa regions have seen declining area and production of chickpea in the last 14 years (Akibode and Maredia1, 2011).

World chickpea yields have increased by 10% from 1997 to 2010.Yields in South Asia, the leading producer of chickpea, increased by 5% in the same period. In Middle East and North African regions, the next important chickpea producing regions, yields declined by 2%. The region of South East Asia saw chickpea yields double in the last 14 years from 0.6 t $ha^{-1}$to 1.2 t ha^{-1} (Akibode and Maredia1, 2011).

India is by far the largest chickpea growing country in the world. The two South Asian countries (India and Pakistan) together cover more than 75% of total world chickpea area. The other top chickpea growing countries from the developing world include Iran and Turkey (5% share in world chickpea area each), and Myanmar and Ethiopia (2% share each). Mexico ranked next followed by many other small producers having less than 1% share in world chickpea area (Akibode and Maredial, 2011).

2.4 Chickpea Sub-sector in Ethiopia

Chickpea is one of the major pulse crops (including faba bean, field pea, haricot bean, lentil and grass pea) in Ethiopia and in terms of production, it is the second most important legume crop after faba beans (Menale et al., 2009). It contributed about 16% of the total pulse production during 1999-2008 and the total annual average (1999-2008) chickpea production was estimated at about 173 thousand tones.

2.4.1 Production, productivity and future potential

The largest growing regions of chickpea in Ethiopia are Amhara, Oromia and few districts of Tigray and SNNPR (EEPA, 2004;FDRE, 2010). Although chickpea is widely grown in Ethiopia, the major producing areas are concentrated in the two regional states of Amhara and Oromia. These two regions cover more than 90% of the entire chickpea area and constitute about 92% of the total chickpea production (Menale *et al.,* 2009).

The top 7 chickpea producing zones (North Gondar, South Gondar, North Shewa, East Gojam, South Wello, North Wello and West Gojam) are found in Amhara region and account for about 80% of the country's chickpea production. In the Oromia region, the major producing zones are West Shewa, East Shewa and North Shewa, which account for about 85% of the total area and production in the regional state.

Chickpea is grown widely across the highlands and semi-arid regions of the country (Geletu *et al.*, 1996). According to the recent estimation of CSA (2011) the total production of chickpea in Ethiopia was about 284,639.8 tons from an area of 213,187 ha. It is less than the total production obtained from 2008/09 which was 312,080.0 tons from 233,440 ha area. Therefore, chickpea showed a decreasing trend both in terms of production and total area coverage in 2009/10 as compared to during 2008/09. However, in 2012 the area increased to 231,000 ha with production volume of more than 400,000 tons, with productivity of 1.73 t ha^{-1}(CSA, 2012), while global productivity is less than a ton ha^{-1}(Akibode and Maredial, 2013).

The two types of chickpea, Kabuli and Desi, are currently produced in Ethiopia. The production of Kabuli types is currently limited to few areas and covers about 25 to 30%(personal communication). Desi type chickpea is traditionally widely grown in the country.

Several new Desi and Kabuli type chickpea varieties have been developed by DZARC through collaborative research programs involving ICRISAT and ICARDA (Shiferaw et al., 2007). Most of the improved chickpea varieties with their appropriate agronomic practices have been demonstrated to farmers particularly in the neighboring districts (woredas) such as Ada'aLiben, Akaki and Gimbichu for further dissemination of the technologies. Although these woredas are well known for their production of desi type chickpeas, they also constitute leader farmers in the production and marketing of high-value improved Kabuli type chickpeas.

Yields of chickpeas in the majority of traditional smallholding farms range from 0.3-0.6 t ha^{-1}. However, improved varieties developed by Ethiopian Agricultural Research Organization (EIAR) reported to yield up to 2.9 t ha^{-1}(EEPA, 2004). According to the recent estimation of CSA , (2011) the productivity of chickpea in Ethiopia shows a slight decrease or remained constant in 2009/10 (1.335 t ha^{-1}) as compared to that obtained in 2008/09 (1.337 t ha^{-1}).There is a wide potential to increase the production by utilizing improved varieties in the future. The chickpea development plan prepared by MOA estimated to achieve 1.4 million tons of chickpeas from 509,749 ha as a long-term plan (EEPA, 2004). This is possible not only by the use of improved varieties but also by the use of proper agronomic practices (such as appropriate plant spacing, land preparation and other cultural practices) bridging the gaps and solving the problem through research work.

2.4.2 Economic importance

The crop provides an important source of food and nutritional security for the rural poor, especially those who cannot produce or cannot afford costly livestock products as source of essential proteins. The consumption of chickpea is also increasing among the urban population mainly because of the growing recognition of its health benefits and affordable source of proteins (Shiferaw *et al.*, 2007). In Ethiopia chickpeas are consumed widely fresh as green vegetables, sprouted, fried, roasted and boiled forms (EEPA, 2004).

Chickpea seed has 25.3-28.9% protein, 38-59% carbohydrate, 3% fiber, 4.8-5.5% oil, 3% ash, 0.2% calcium and 0.3% phosphorus. Digestibility of protein varies from 76-78% and its carbohydrate from 57-60% (Hulse, 1991).

Raw whole seeds contain per 100 g: 357 calories, 4.5-15.69g moisture, 0.8-6.4g fat, 0-225mg b-carotene, 0.21-1.1mg thiamin, 0.12-0.33mg riboflavin and 1.3-2.9mg niacin (Duke, 1981; Huisman and van der Poel, 1994).The limiting amino acid concentrations are 0.52mg for methionine, 1.45mg for lysine and cystine, 0.71mg for threonine and 0.16 mg for tryptophan (Williams *et al.,* 1994). It is also used to rehabilitate depleted fallow lands by playing active role in crop rotation practices/programs.

In the export market, chickpea contributes a significant portion of the total value of pulse exports. For example, chickpea constituted about 48% of the pulse export volumes in 2002.During this period of time, the exported volume accounted for about 27% of the total quantity of chickpea production while the balance remained for domestic market (Shiferaw et al., 2007). Due to the improvement of production in the country and new markets demand, Ethiopian chickpeas have gained an important place in India and Pakistan (2000-2002). In 2002 alone the country exported 48,549.9 tons of chickpeas valued at 14.6 million USD mainly to Pakistan, India, UAE, Panama and Bangladesh, taking 73, 7, 6.5, 5.5 and 2.5 percent share of the export (EEPA, 2004).

The average annual chickpea export was 34,308 MT, with an estimated annual foreign currency earnings equivalent to US$ 20.93 million each year between 2005 and 2010. Both the volume and value for chickpea showed more accelerated growths than those for common bean. Destinations of Ethiopian chickpea export include 32 countries in Asia, the Middle East, Africa and Europe. Pakistan, UAE and Sudan accounted for about 34%, 27% and 14% of the total volume. Bangladesh, India, Singapore, Saudi Arabia, Djibouti, Israel and Jordan were among the top 10 destinations for Ethiopian chickpea export. For many smallholder farmers this meant improved income, food security, nutrition and investment in businesses such as seed production and livestock raising. Overall, the increased productivity and production have helped Ethiopia to increase its revenue and diversify exports, instead of relying totally on few export cropping such as coffee (Tsedeke, 2011).

2.5 Plant Density

Chickpea is grown at a plant density of 33 plants m^{-2} in a flat- or broad bed-and-furrow system at ICRISAT Asia Center, Patancheru, India. The plant density ranges from 25 to 30 plants m^{-2} in a ridge-and-furrow system. Tall and erect cultivars gave high seed yield at a higher plant density (25 to 30 plants m^{-2}) due to their apical pods (Calcagno *et al.* 1988).

The optimum plant population depends upon the genotype and the environmental conditions under which the crop is grown. In India, a population of 33 plants m^{-2}appears to be the best (Saxena, 1980; Singh, 1983). In Iran, yield increase was recorded with an increase in population up to 50 plants m-^{2}under irrigated conditions and up to 25 plants m^{-2}in non irrigated spring-sown chickpea (Anonymous, 1976). A decrease in row spacing from 60 cm to 30 cm increased the yield of winter chickpea by 52% in western Jordan (Kostrinski, 1974). A similar response was observed in Cyprus (Photiades ,1984). In Syria, when the population density was raised from 18 to 28 plants m^{-2}in winter, there was a significant increase in yield, but the same response was not observed in the spring-sown crop (Saxena, 1980). Compact, upright-growing plants responded better to increased plant density than the spreading type (Singh, 1981). In Bangladesh, a plant density of 30 plants m^{-2}at a seed rate of 60 kg $ha^{-1}$was found to be appropriate for good growth and yield (Paramanik et al., 1990).

Higher plant densities have been reported to be more appropriate for late sowing. At Kanpur (India) chickpea sown in early December at densities of 33 plants $m^{-2}$and 44 plants m^{-2} gave yields of 1.96 t $ha^{-1}$and 2.11 t ha^{-1} ,respectively (Ali, 1988). Shakhawat and Sharma (1986) reported that in late-sown conditions, increase in seed rate (from 70 kg $ha^{-1}$to 140 kg ha^{-1}), reduction in row spacing (from 30cm to 22.5 cm), and sowing in bidirectional rows gave a higher yield.

2.5.1 Spacing and Optimum Population

Both too narrow and too wide spacing do affect grain yields through competition (for nutrients, moisture, air, radiation, etc) and due to the effect of shading. In the latter case (too wide spacing), yield reduction can occur due to inefficient utilization of the growth factors. Normally, as population increases yield also increases proportionally. After, it reached a certain level the yield declines.

Population density is also dependent on the moisture availability and nutrient status of the soil. Hence, optimum planting density should be determined through research works (Solomon, 2003).The spacing between stands is largely determined by the extent of the root and shoot systems of the crop plant in question.

The spacing between stands per hectare, in turn, determines the number of stands per hectare (Onwueme and Sinha, 1991). The number of stands per ha, and the number of plants per stand together determine the number of plants per ha, or the plant density.

A number of factors also influence spacing like fertility status of the soil, growth pattern of the crop and cultural practices (Martin et al., 1976). In addition, in row crops, the space between rows as well as within rows depends up on factors such as moisture, type of crop, the climate and the variety of a particular crop. Competition in cultivated crop is commonly between plants of like or similar genotype, all sown at the same time and each with similar environmental conditions. often, the immediate objective in planning studies on plant densities to determine the optimum sowing rate, the data rarely included a sufficiently wide range of densities to permit the definition of the relationship of density to yield, however, a few studies have varied densities from low to very high values. A major factor influencing optimum seed rate for any particular crop is the genotype (Mekonnen, 1999).

Genotype by plant density interaction was found to be evident in faba bean (Amare et al, 1993), field pea (Rezene, 1994), chickpea and lentil (Million, 1994). The population and growth habit interaction affected seed yield in soybean and the interaction was also large for plant height. However, growth habit differences were consistent across populations for days to maturity and number of main stem nodes (Ouattara and Weaver, 1994).

2.5.2 Importance of spacing and optimum population

Establishment of optimum population per unit area of the field is essential to get maximum yield. Under conditions of sufficient soil moisture and nutrients, higher population is necessary to utilize all the growth factors efficiently. The level of plant population should be such that maximum solar radiation is utilized. The full yield potential of an individual plant is fully exploited when sown at wider spacing. Yield per plant decreases gradually as plant population per unit area increases. However, the yield per unit area is increased due to efficient utilization of growth factors. High plant density brings out certain modifications in the growth of plants such as an increase in plant height, reduction in leaf thickness, alteration in leaf orientation, and leaves become erect, narrow and are arranged at longer vertical intervals to intercept more sun light (Singh and Singh, 2002).

The crop plants should cover the soil as early as possible to intercept maximum sunlight to produce higher dry matter as the intercepted solar radiation and dry matter production are directly related. Closely spaced and quick growing crops like soybean which can intercept more light within a short period gives higher yield as compared to wider spaced crops. As such, for the proper light interception at various growth stages, optimum plant population is necessary.

As plant density increases, the amount of dry matter in vegetative parts also increases. Both the biological and economic yields increase with increasing plant population up to a certain point and subsequently no addition in biological yield can be obtained and economic yield decreases. Therefore, the optimum plant population of individual crop should be worked out under suitable environmental conditions (Singh and Singh, 2002).

2.6 Effect of Plant Spacing on Growth, Yield Components and Yield of Chickpea

The plant population density that produces maximum yield or optimum plant population density of crops, including chickpea, is affected by genotype, environment and their interaction. A range of optimum plant population density has therefore, been reported for various chickpea varieties and environments. A great variation exists in number of plants m^{-2} for obtaining higher yield of chickpea. Based on the size of the seed, EARO, 2004 and FDRE, 2010 recommended that the optimum seed rate for chickpea in Ethiopia ranges from 60-140 kg ha^{-1}. Million , 1995 reviewed that seeding rate of chickpea in the Central Highlands of Ethiopia showed no or minimal yield differences. According to this study, seeding rates of 70-80 kg $ha^{-1}$was recommended for chickpea. Whereas, AUA, 1994 showed that seed yield on Mariye chickpea variety was significantly influenced by seeding rates (i.e., 70, 80, 90 and 100 kg ha^{-1}) effects at Debre-Zeit and the highest seed yield of 1.7 t $ha^{1}$was obtained from the lowest seeding rate (70 kg ha^{-1}) and compared with this rate, sowing chickpea at seeding rates of 80 and 90 kg ha^{-1}resulted in 35 and 45% seed yield reductions at Debre-Zeit. However, the results from Akaki showed that seed yield was non-significantly influenced by seeding rates.

A field experiment conducted in 2005 at Kermanshah (Iran) showed significant differences between the planting dates and planting density effects on plant height, number of branches $plant^{-1}$, distance between 1st pod to soil, number of pods $plant^{-1}$, number of grains $plant^{-1}$, biological yield and grain yield (Shamsi, 2005) and reported that the maximum grain yield belonged to plants sown on 6th November at a row spacing of 30 cm. However, the maximum number of pods $plant^{-1}$and grains $plant^{-1}$belonged to plants spaced at 40 cm row spacing.

Ali et al., 1999 indicated that the increase in intra and inter- row spacing of chickpea mutant (CM2) significantly increased the plant height, numbers of pods $plant^{-1}$ and $plot^{-1}$and suggested that to obtain better yield from (CM2), crop should be sown at 23 plants m^{-2} instead of previously reported optimum population of 33 plants $m^{-2.}$ Mirazaei et al. ,2010 revealed that pod number, number of empty pods, and number of seeds per pod, weight of hundred seed, seed yield, biological yield, and harvest index were significantly influenced by seeding densities and maximum numbers of empty pods $plant^{-1}$, seeds pod-^{1}, seed weight and biological yield were significant at the density of 25 plants m^{-2}. However, maximum harvest index and highest grain yield were achieved at a density of 45 plants m^{-2}.

Growth and grain yield response of gram (*Cicer arietinum L.*) cultivar Paidar-1991 to different seeding densities (40, 50, 60, 70 and 80 kg ha^{-1}) and row spacing's (30, 45 and 60 cm) indicated that the seed yield and growth characteristics such as plant height, number of branches plant^{-1}, number of seeds pod$^{-1,}$ and 1000-seed weight were influenced significantly by seeding densities (Sharar et al., 2001). According to this study, maximum seed yield of 2299.56 kg ha^{-1}was obtained at seeding density of 70 kg ha^{-1}, whereas row spacing had no significant effect on plant height, seed yield and yield components.

A research conducted to determine the best equidistance arrangement with different densities of chickpea (Cicer arietinum var. Philip) in Iran showed non-significant effect on seed yield, seed number pod^{-1}but it had significant effect on pod number plant^{-1}, seed weight and number of lateral branches (Biabani, 2007). The results indicated that the highest seed yield (4665) was obtained from treatment row spacing and plant to plant distance of 18 cm x 18 cm.

Ahmadkhan *et al.* , 2010 concluded that 45 cm row spacing with 75 kg seed rate ha^{-1}of chickpea affected positively different agronomic parameters like number of pods plant^{-1}, number of seeds pod^{-1}and 100 seed weight which ultimately contributed to increased biological yield, grain yield and harvest index further, 45 cm single row spacing with 75 kg seed rate ha^{-1} was the optimum planting geometry for efficient light interception and photosynthetic activity and same was proposed to the farmers for better yield in chickpea under given environmental conditions.

Beech and Leach, 1989 grew chickpea at row spacings of 18, 36, 53 and 71 cm with plant population densities of 14, 28, 42 and 56 plants m^{-2} and reported that row spacing had a little effect on above ground dry matter production and seed yield, whereas Singh and Singh, 1989 obtained the highest seed yield of 1.99 t ha^{-1}at row spacing of 45 cm. Sarwar, 1998 reported that row spacing significantly influenced the number of branches plant^{-1}and number of seeds plant^{-1}, whereas, plant height, number of seeds pod^{-1}, 100-seed weight, biological yield, seed yield and harvest index were not affected significantly by row spacing.

3 MATERIALS AND METHODS

3.1 Description of Experimental Site

The experiment was conducted from september 25, 2016 to January 25, 2017 at Tseda, located at 30^0 N latitude and 20^0 E longitude (15km South-East of Gondar city) and at an altitude of 1900 masl. It receives annual rainfall of 1050 mm and has average annual minimum and maximum temperatures of 16 ^{0}c and 28^0c and, respectively (FAO-UNDP, 1990). The soil is deep black soil.

3.2 Description of Variety Used for the Study

Habru Kabuli type chickpea was used for the experiment. It was released by Debre Zeit Agricultural Research Center (DZARC) in 2007 (MoARD, 2010). Days to maturity of this variety is 136, with 100 seed weight of 31g and yield of 3.2-3.6 t ha^{-1}.

3.3 Treatments and Experimental Design

A field experiment consisting of factorial combination of 4 inter- row spacing's (20, 30, 40 and 50 cm) and 3 intra- row spacing's (5,10 and 15 cm) was laid out in a randomized complete block design (RCBD) with three replications. These treatment combinations are:

1. 20 cm × 5 cm	7. 40 cm × 5 cm
2. 20 cm x 10 cm	8. 40 cm x 10cm
3. 20 cm x 15 cm	9. 40 cm x 15 cm
4. 30 cm x 5 cm	10. 50 cm x 5 cm
5. 30 cm x 10 cm	11. 50 cm x 10 cm
6. 30 cm x 15 cm	12. 50 cm x 15 cm

3.4 Management of the Experiment

The plot size was 3 m x 2.4 m and was leveled manually. The width between plots and between blocks was 0.5 m and 1.5 m, respectively. As per the treatments there were 12, 8,6 and 5 rows for 20, 30, 40 and 50 cm inter-row spacing's, respectively. The numbers of plants in each row were 60, 30 and 20 for intra- row spacing's of 5, 10 and 15 cm, respectively. The seeds were planted on September 9, 2016 by placing a single seed per hole at a specific inter- and intra- row spacing. Weeding was done thrice during the growth of the crop. The first weeding and inter tillage activities were done 25 days after emergence, the second and the third weeding was practiced 30 days and 50 days after the first weeding, respectively.

3.5 Soil Analysis

A composite initial soil samples from 0-30 cm soil depth were taken from the experimental site before planting following the procedures of surface soil sampling i.e. the entire site were divided into 3 uniform sub-plots and five samples in each sub-plots were taken in a diagonal pattern by vertical insertion of the auger. Then, the samples were air-dried, ground using a pestle and mortar, and allowed to pass through a 2 mm sieve. The soil sample were taken to soil laboratories and analyzed for selected physico-chemical properties mainly for textural analysis (percent sand, silt and clay), soil pH, total nitrogen, organic matter content, available phosphorous (P), exchangeable potassium (K+) and cation exchangeable capacity (CEC).

The organic matter content of the soil is determined as suggested by Walkely and Black procedure (1934) and total nitrogen by Micro - Kjeldhal method (Jackson, 1958). Soil reaction (pH) was determined by pH meter with 1:2.5 soil to solution ratio via a glass electrode attached, and cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH4OAC) and displacing it with 1N NaOAC (Chapman, 1965). Available phosphorous was determined by the Olsen method (Olsen et al., 1954) and exchangeable potassium by flame photometer.Soil texture analysis were performed by Bouyoucous hydrometer method (Day, 1965).

3.6 Data Collection

3.6.1 Phenological Data

Days to emergence was recorded as the number of days from sowing to when 50% of the plants emerged in each plot. Similarly, number of days to flowering was recorded when 50% of the plants reached flowering stage. Days to maturity was recorded as the number of days from planting to the stage when 90% of the plant reached physiological maturity, i.e. when the plants and the pods turned pale yellow in colour based on visual observation.

3.6.2 Growth, yield components and yield

Number of primary branches was taken by counting the number of primary branches from the main stem at harvest. The aboveground biomass was sun dried until constant weight and its total and grain weight was recorded for calculating the harvest index. Number of pods per plant was recorded by counting the total number of pods from five plants and their average was taken as number of pods per plant at harvest. The twenty pods were randomly picked from the total pods as above and the seeds were counted to determine their number per pod.

The initial crop stand count was recorded by counting the total number of plants per net plot area 25 days after planting and final plant stand count was taken from net plot areas when the plants attained physiological maturity, the percent survival was calculated to determine the change in stand count due to competition and pest effect. One hundred grains from the bulk of harvested produce was counted from each plot and their weight was recorded as 100-seed weight adjusted at 10% grain moisture content.

Grain yield from the net plot area of each plot was recorded by measuring the grain yield and adjusted at 10% grain moisture content using the formula :Adjusted grain yield = Recorded grain yield × 100-M/100-D; where M is the measured moisture content and D is the designated moisture content (10.0%).

3.7 Statistical Data Analysis

The various agronomic data collected were subjected to analysis of variance (ANOVA) appropriate to factorial arrangement in RCBD according to the Generalized Linear Model (GLM) of SAS and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the factors and interactions were found to be significant, the means were compared using the least significant differences (LSD) test at 5% level of significance.

4 RESULTS AND DISCUSSION

4.1 Physico - Chemical Properties of Experimental Soil

According to the laboratory analysis, the soil texture of the experimental area was clay (Table 1). The soil texture (proportion of sand, silt and clay in the soil) that controls water content, water intake rates, aeration, root penetrate ion, and soil fertility. Though the best suited soils for chickpea are deep loam or silty clay loam soil (ICRISAT, 2010), but the texture of the experimental area was good (Olson and Dean, 1965). The pH of the soil was 6.0, which is moderately acidic. Miller and Donahue (1997) indicated that plants grow well between pH 5.5 and pH 8.5. Chickpea specifically grows well under the pH range of 6.0 to 8.0 (ICRISAT, 2010).The CEC of the soil of the experimental site was determined to be 22.6 cmol/kg.

Table 1. Major physico -chemical properties of the experimental soil

No soil character		values
1.pH (by 1: 2.5 soil water ratio)		6.0
2 Organic matter (%)		2.46
3 Total nitrogen (%)		0.168
4 Available phosphorous (ppm)		2.48
5 Cation exchange capacity (cmol(+)/kg)		22.6
6 Exchangeable potassium (meq /100g soil)		0.1443
7 Soil texture:	Sand (%)	30.5
	Silt(%)	9.1
	Clay(%)	602

According to the rating made by Landon (1984), this value lies in the lower range (15-25 cmol/kg), means the soil, is not satisfactory for agricultural production. Further, the analysis indicated that the experimental soil had values of 0.168%, 2.460%, 2.480 ppm and 0.144 meq 100 g^{-1} with respect to total nitrogen, organic matter, available phosphorous and exchangeable potassium, respectively (Table 1).

When the results of the analysis were compared with the broad ratings made by Metson (1961), all the values lie in the lower range for plant growth.

4.2 Phenological Parameters

4.2.1 Days to 50% emergence

There was no significant difference among inter- and intra- row spacing with respect to days to 50% emergence as the plants emerged in about nine days after planting (Appendix Table 2). The adequate amount of soil moisture during planting assisted by irrigation might have triggered the seeds to germinate and emerge from the soil uniformly. This result was in agreement with that of Amato et al.(1992) where seed germination and establishment rate of faba bean were not affected by the sowing rate. Similarly, Gebre (2006) also reported no significant effect of the inter- and the intra- row spacing as well as their interactions on days to 50% emergence of sesame.

4.2.2 Days to 50% flowering

The main effect of inter-row spacing's was highly significant ($P<0.01$) while intra- row spacing's was not significant (table 2) and their interaction had no significant effect on days to 50% flowering (Appendix Table 1). Days to flowering significantly decreased from 51.56 to 49.78 days as the inter-row spacing's increased from 20 cm to 50 cm (Table 1). This might be due to the fact that wider inter - row spacing had a better light interception as compared to the narrower row spacing resulting in less number of days to flower as chickpea needs direct sunlight coverage for its various physiological processes. Further, more nutritional area available in wider row spacing might have caused the crop to flower earlier than the closer spacing. On the other hand, in narrower inter - row spacing's due to competition for nutrients, moisture and space, the crop came in to flowering lately. Besides, moisture and nutrient utilization were more luxurious in the wider spaced inter rows as compared to the narrower row spacing. In agreement with this result, Farag and EI-Shamma (1994) reported that the wide plant spacing of 50 cm reduced number of days to flower in broad bean than 40 cm plant spacing. In contrast Turk et al. (2003) found that the denser plant population hastened days to flowering in lentil. While, Abubaker (2008) found no significant effect of plant population on days to flowering in common bean. Similarly, in the wider intra-row spacing, the plants attained 50% flowering earlier than the narrower spacing (Table 2). But Oad et al.,(2002) who worked on safflower reported that inter- and intra- row spacing did not affect significantly the number of days to 50% flowering. Therefore, it seems that the influence of plant population on days to flower initiation varies from crop to crop as well as the prevailing environmental conditions under which the crops are grown.

Table2. Main effects of inter- and intra- row spacing on days to 50% emergence, days to 50% flowering and on days to physiological maturity of chickpea.

Treatment	Days to 50% Emergence	Days to 50% flowering	Days to 50% physiologcal maturity
Inter-row spacing(cm)			
20	9.67[a]	51.56[a]	104.56[a]
30	9.22[a]	50.44[b]	103.44[b]
40	9.11[a]	50.17[bc]	102.61[c]
50	9.00[a]	49.78[c]	101.61[d]
LSD(0.05)	0.177	0.59	0.74
Inta-row spacing(cm)			
5	9.25[a]	50.54[a]	103.29[a]
10	9.17[a]	50.50[a]	102.96[a]
15	9.33[a]	50.42[a]	102.92[a]
LSD(0.05)	**0.72**	0.47	0.58

4.2.3 Days to physiological maturity

The main effect of inter-row spacing’s was highly significant (P<0.01) while intra- row spacing’s was not significant (table 2) and their interaction had no significant effect on number of days taken by the crop to reach physiological maturity(Appendix Table 1).

The narrowest inter row spacing (20 cm) took 104.56 days to attain physiological maturity which was significantly enhanced by wider spacing’s of 30, 40 and 50 cm spacing (Table 2). The reason for this may be that in the wider inter row spacing, there existed a lower competition for resources like moisture and essential nutrients than the narrower inter- row spacing. In addition, light would be intercepted better in the wider inter- row spacing’s as compared to the narrower inter- row spacing’s and also the better free air circulation in the canopy of the widely spaced rows could have its own contribution to shorter days for maturity.

The prolonged days to maturity in the case of narrower intra row - spacing could be because of high competition for available resources in the soil, poor light interception and air circulation in the canopy as compared to the wider inter- row spacing. The present result is in line with those of Oad *et al.,* (2002) where in, wider inter- and intra-row spacing hastened maturity of safflower. But in disagreement with the report of Holshouser and Joshua ,2002 who found no significant effect of row spacing on maturity of soybean. In general, the differences in days to flowering and physiological maturity are very small which may not be practically important though statistically significant.

4.3 Growth Parameters

4.3.1 Plant height at maturity

Main effect of inter- and intra- row spacing’s had highly significant (P<0.01) effect (table 3) but their interaction had not significant effect on plant height of the chickpea crop (Appendix Table 2). The interaction of 20 cm inter- and 5 cm intra- row spacing resulted in significantly taller plants (14.22 cm) while, the plants in 40cm inter-and 15cm intra-row and 50 cm inter- and 15 cm intra- row spacing's were the shortest in height (13.02 cm) and (13.11 cm) respectively (Table 3). These result might be due to the fact that as the spacing between plants decreased the inter-plant competition for light increased while, sparsely populated plants intercepted sufficient sunlight that enhanced the lateral growth. In agreement with this, Fleton *et al.* (1996) and Sharar et al. (2001) reported that height of chickpea plant was more in higher plant population treatments due to more competition for light. Similarly, Parvez et al., (1989) and Singh and Singh , (2000) indicated that plant height significantly increased with the increase in plant density primarily because of lower amount of light intercepted by plants resulting in increased inter-node length. Taj et al. (2002) found more competition for light under narrow spacing that resulted in taller plants while, at wider spacing light distribution was normal. Moreover, Shamsi and Kobraee (2009) who worked on spacing experiment on soybean observed that increasing the density of plants led to significant increases in plant height. In contrast, Shahein *et al.* (1995) reported that plant height was not affected by increasing plant density of faba bean.

Table 3. Main effects of inter- and intra- row spacing on plant height (cm)

Treatment	Plant height(cm)
Inter-row spacing(cm)	
20	14.22^{a}
30	13.67^{ab}
40	13.03^{b}
50	13.11^{b}
LSD(0.05)	1.038
Intra-row spacing(cm)	
5	13.56^{ab}
10	13.92^{a}
15	13.04^{b}
LSD(0.05)	0.81

4.3.2 Number of primary branches

Analysis of variance revealed highly significant ($P<0.01$) effect of the main effects of inter- and intra- row spacing's and significant effect ($P<0.05$) of their interaction on the number of primary branches per plant (Appendix Table 2). As a result , in response to the interaction of 50 cm inter and 15 cm intra-row spacing resulted in the highest number of primary branches plant^{-1}which was statistically at par with the interaction of 50 cm inter- and 10 cm intra-row (Table 4). The lowest number of branches (4.4) was found due to the interaction of 20 cm inter- and 5 cm intra-row spacing's.

The differential responses among the interaction of inter and intra- row spacing might be due to differences in the access to growth factors by the plants grown under their respective environments. The increased number of branches under lower plant densities could be attributed to higher sunlight interception for photosynthesis. In contrast, the decreased number of branches in the narrower plant spacing might be due to the high competition for the resources and with the overlapped plant canopy, the crop might have been subjected to lower interception of sunlight which led to lower photo assimilation. This also indicated the plasticity response of plants to various plant spacing.

These results are in agreement with the findings of Mehmet (2008) who obtained increased number of branches at the wider plant spacing for soybean and the reason assigned for this was more interception of sunlight for photosynthesis, which may have resulted in production of more assimilate having been partitioned more towards the development of branches. In agreement with this result, Togay et al. (2005) and Bakry et al. (2011) reported that the number of primary branches decreased with the increase in density of chickpea.

Table 4. Interaction effect of inter- and intra- row spacing on number of primary branches of chickpea .

Intra-row spacing(cm)	Inter-row spacing(cm)			
	20	30	40	50
5	4.4^{c}	6.26^{a}	4.33^{b}	5.72^{a}
10	4.5^{b}	5.57^{ab}	4.95^{b}	6.28^{a}
15	4.6^{b}	3.84^{c}	5.8^{a}	6.3^{a}
LSD(0.05) = < 0.0001		CV = 5.8		

4.3.3 Plant Stand count

The main effects of inter- and intra- row spacing's and their interactions were significant with respect to final stand count of chickpea as compared to the initial count. This might be due to competition for light, nutrient, moisture and effect of disease or Fusarium wilt (table5).

Table 5. Interaction effect of inter- and intra- row spacing on stand count percentage of chickpea at harvest

Inter-row spacing(cm)	Inter-row spacing			
	20	30	40	50
5	97.83^{a}	97^{a}	97.75^{a}	96.67^{a}
10	90.25^{b}	90.97^{ab}	96.5^{a}	96.5^{a}
15	94^{bc}	91.5^{c}	97^{a}	95^{ab}
LSD(0.05) = 0.025	CV= 2.48			

4.4 Yield components

4.4.1 Number of pods per plant

The main effects of inter- and intra- row spacing's on the number of pods plant^{-1} were highly significant (p<0.01) but their interaction was not significant (P<0.01) (Appendix Table 3). The highest number of pods plant^{-1} was obtained with the interaction effect of 50 cm inter- and 15 cm intra- row spacing's. In general, the number of pods plant^{-1}increased with the increase in inter row spacing at the same level of intra row spacing. The lowest number of pods plant^{-1} was found in the closest spacing, i.e. 20 cm inter- and 5 cm intra-row spacing which was significantly lower than the other interactions (table 6).

The difference among the inter row spacing in response to intra row spacing on number of pods might be due to the fact that, as the plant population increased there was high competition for the growth factors as compared to wider spacing which had impact on the number of pods per plant. The reduced competition for light and reduced overlapping from adjacent chickpea plants could have enabled the plants grown at wider spacing to utilize its energy for more branching (Table 6) and subsequently, the greater number of pods plant$^{-1.}$ In agreement to the present result, Khan et al. (2010) reported higher number of pods plant^{-1}(41.47) in the wider inter row spacing(45cm) of chickpea. Similarly, Al -Abdselam and Abdi (1995), Hodgson and Blackman (2005) and Abdel (2008) who worked on faba bean reported that the development of more and vigorous leaves on low plant density helped to improve the photosynthetic efficiency of the crop and supported higher number of pods.

4.4.2 Number of seeds per pod

The analysis of variance showed a highly significant (P<0.01) effect of the main effects of inter - and intra- row spacing, but their interaction had no significant effect on the number of seeds pod^{-1}(Appendix Table 3). Significantly higher number of seeds pod^{-1}(1.23) was obtained at 50 cm than the other inter- row spacing (Table 6). There was no significant difference between 30 and 40 cm inter row spacing while 20 cm inter row spacing recorded significantly lower number of seeds pod^{-1} than the other inter row spacing. The plants grown in plots with 50 cm inter- row spacing had 11.8, 5.1, 6.0 % higher number of seed pod^{-1} respectively, than the plants grown in 20, 30 and 40 cm inter row spacing. This might be due to the fact that, as the plant population increased there was high competition for the growth factors as compared to wider spacing which had impact on the number of seeds per pod.

Yet, whole plant growth and competitive ability depends not only on the photosynthetic rate of individual leaves, but also on the geometry and dynamics of a plant's canopy, and the pattern of energy allocation among all organs (Bange and Caton, 2006).

Table 6. Main effects of inter- and intra- row spacing on the number of pods per plant, number of seeds per pod, and hundred seed weight (g) of chickpea.

Treatment	number pods per plant	number of seeds pod	hundred seed weight
Inter-row spacing (cm)			
20	20.49^{d}	1.10^{c}	29.61^{c}
30	23.47^{c}	1.17^{b}	30.66^{b}
40	26.60^{b}	1.16^{b}	30.87^{c}
50	31.39^{a}	1.23^{a}	31.34^{a}
LSD	1.32	0.04	0.32
Intra-row spacing’s(cm)			
5	23.83^{c}	1.12^{b}	30.49^{a}
10	25.73^{b}	1.18^{a}	30.59^{a}
15	26.91^{a}	1.19^{a}	30.74^{a}
LSD	1.038	0.035	0.25

4.4.3 Hundred Seed weight

The main effects of inter- row spacing's were highly significant ($P<0.01$) while effects of intra-row spacing's were not significant, and their interaction had no significant effect on the hundred seed weight of chickpea (Appendix Table 3).The highest hundred seed weight (31.34g) was observed with 50 cm inter- row and 15cm intra-row spacing which had no significant difference with 40 cm inter-row spacing. On the other hand, no significant difference in 100 seed weight existed between seeds obtained under 30 and 40 cm inter- row spacing. However, 20 cm inter row spacing had significantly the lowest 100 seed weight compared to the other interspacing's (Table 6).

Decreasing inter- and intra- row spacing might have increased inter specific competition which eventually caused reduction in weight of seeds. Moreover, decreasing plant density might have caused more sunlight to penetrate the canopy that made plants to benefit more from the natural environment. Thus, this might have caused an increase in number of branches and the increased level of photosynthesis resulting in more assimilates trans located and stored in seeds. In agreement with the result obtained, Solomon (2003) reported that hundred seed weight increased from 17.5 g to 19.56g as plant spacing increased from 40 cm × 7 cm to 40 cm× 16cm in haricot bean. Similarly, Al-Abduselam and Abdu (1995), Turk and Tawaha (2002) and Matthews *et al.* (2008) also reported that hundred seed weight of faba bean was negatively related with plant density. Moreover, Khan *et al.* (2010) reported higher hundred seed weight (29.87g) in the wider inter row spacing of 45 cm than 30 cm inter row spacing of chickpea. However, the result of this experiment were not in line by with those obtained by Turk *et al.* (1980) who reported that individual seed weight is rarely affected by growth factors except in case of severe water stress and hot desiccating winds that cause forced maturity. Similarly, Lemlem (2011) also obtained no significant effect of plant density on hundred- seed- weight of soya bean.

4.5 Yield and Harvest Index

4.5.1 Above ground dry biomass yield (kg ha^{-1})

The analysis of variance revealed that the main effects of inter- row and intra- row spacing showed a highly significant (P<0.01) effect on above- ground dry biomass. Moreover, the interaction effect of inter row- and intra row-spacing had also a highly significant (P<0.01) effect (Appendix Table 4). The highest above ground dry biomass (6555 kg ha^{-1}) was recorded at 20 cm ×5 cm spacing combination and the lowest above ground dry biomass (3896kg ha$^{-1)}$ was recorded at 50 cm ×15 cm spacing combination (Table 7). For all of the inter row spacing, the highest number of above ground dry biomass were recorded as the intra- row spacing decreased. The highest total dry biomass at the highest density of plants might be due to more number of plants per unit area. However, if the number of plants per unit area keeps on increasing, the aboveground dry biomass will reduce as there is lodging problem and lower photosynthetic efficiency in highly crowded plant population.

Table 7. Interaction effect of inter- and intra-row spacing on above ground dry biomass yield (kg ha$^{-1)}$ of chickpea

Intra-row Spacing's (cm)	Inter-row spacing's (cm)			
	20	30	40	50
5	6555^{a}	6427^{b}	5747.5^{c}	5148^{d}
10	5755^{a}	4900^{b}	4504 ^{c}	4301.6^{d}
15	4890^{a}	4294^{b}	4055^{c}	3896^{d}
LSD(0.05) =0.0001		CV(%) =0.29		

In agreement with this study, Solomon (2003) reported that dry biomass per ha significantly increased with increased plant density (40 cm ×10 cm) on haricot bean. Similarly, Singh and Singh (2002) reported increment of total dry biomass with increasing plant population of soya bean up to a certain point and subsequently no addition in biological yield can be obtained thus decreased economic yield.

4.5.2 Grain yield (kg ha^{-1})

The main effects of inter- and intra- row spacing's and their interaction showed a highly significant ($P<0.01$) effect on grain yield (Appendix table 4).The interaction of 20 cm inter- and 5 cm intra- row spacing resulted in the highest grain yield (3036 kg ha^{-1}). The lowest grain yield (1400 kg ha^{-1}) was recorded with the interaction of 50 cm × 15 cm. The possible reason could be that, when inter-and intra- row spacing was decreased, number of plants per unit area increased, resulting in higher yield. Decreased inter- and intra-row spacing implied high plant density, which is concomitantly equal to high yield with every successful pod formation per plant. However, this could be possible only up to certain level of population. At extremely higher population more than (20 cm × 5 cm), the adverse effect on the yield was noticed which might be due to intense interplant competition and floral abortion. In spite of lower number of branches plant $^{-1}$, number of pods plant^{-1}, number of seeds pod^{-1}and hundred - seed -weight at narrow inter- and intra- row spacing and or their interaction, i.e. 20 cm ×5 cm, the grain yield ha^{-1}was significantly higher as compared to the interaction of wider inter- and intra- row spacing (50 cm ×15 cm) which showed that the main determinant of yield was the plant population which along with other yield attributes contributed towards significant increase in grain yield (Table 8). It can thus be seen that, the total yield per unit area depended not only on the performance of individual plant but also on the number of plants per unit area as confirmed in this study. Further, other reason for seed-yield enhancement under narrow planting could be attainment of sufficient leaf area index (LAI) to produce maximal light interception during the grain formation. But in the wide inter- and intra-row spacing even though the yield per individual plant was higher, since the plant population reduced the grain yield showed decrement. Cooper (1977) and Taylor *et al.*, (1982) concluded similar idea that at narrow-row planting seed yield enhancement in determinate soybean was due to greater light interception during pod filling, and not greater leaf area development and dry matter production before this time. Similarly, Biabani (2011) reported higher grain yield of chickpea at average

(45cm×7.5cm) spacing combination than 35cm×5cm and 55cm×10cm spacing combinations. Moreover, Andrade et al. (2002) and Caliskan et al. (2007) reported increased yield from higher plant populations are primarily the result of increased light interception during grain-filling by the crop canopy of soya bean. This idea was also in agreement with Singh and Singh (2002) who reported that the yield per unit area was increased with increasing plant density due to efficient utilization of growth factors.

Table 8. Interaction effect of inter- and intra- row spacing on grain yield (kg ha^{-1}) of chickpea

Intra-row	Inter-row spacing			
spacing's	20	30	40	50
5	3036^{a}	2828^{b}	2445^{c}	2166.67^{d}
10	2355^{a}	1944.67^{b}	1730.83^{c}	1591.3^{d}
15	1927.78^{a}	1649.33^{b}	1505.67^{c}	1400^{d}
LSD(0.05= 0.001	CV= 0.916			

Further, Norman (1963) and Reddy (2000) reported that too narrow or too wide spacing affect yield due to competition for resources and shading effect. In the case of too wide spacing, yield reduction can occur due to inefficient utilization of the growth factor.

4.5.3 Harvest index

There was a significant difference recorded on the main effects of inter row spacing, intra row spacing and their interaction (Appendix Table 4). The highest harvest index (46) was achieved for the interaction of 20 cm inter- and 5 cm intra- row spacing. The lowest harvest index (36%) was accrued with the combination of wider inter- and intra- row spacing, i.e. 50 cm × 15 cm (table 9). This reduction in harvest index in wider spacing's might be due to the higher vegetative and flower abortion. Similar result was reported by Khan *et al.* (2010) who indicated maximum harvest index (43.66%) in the lowest row spacing (25 cm) of chickpea than 35 cm row spacing.

Table10. Interaction effect of inter- and intra- row spacing on harvest index (%) of chickpea.

Intra-row spacing	Inter-row spacing			
	20	30	40	50
5	46 ^{b}	44 ^{a}	43 ^{a}	40 ^{a}
10	41 ^{a}	40 ^{b}	38 ^{c}	37 ^{d}
15	39 ^{a}	38 ^{b}	37 ^{b}	36 ^{c}

LSD(0.05) = 0.004 CV = 1.37

5 SUMMARY AND CONCLUSION

Chickpea is the most important leguminous food grain in the diets of people in South and West Asia and northern Africa. In Africa, Ethiopia stands first in area (213,187 ha) and production (284,640 t), but third in productivity (1335.2 kg ha-1) after Egypt and Sudan. This clearly indicates the importance of chickpea in Ethiopian agriculture. The crop has a major role in the daily diet of the rural community and poor sectors of urban population and its straw is used for animal feed. Chickpea also fetches good price when sold in local market and hence generates cash to farmers. Despite these facts, the yield of chickpea in Ethiopia is extremely low which can be attributed to factors such as water deficit, diseases, insects, weeds infestations and poor agronomic practices.

It is clear that both too narrow and too wide spacing do affect grain yields through competition (for nutrients, moisture, air, radiation, etc) and due to the effect of shading. In the latter case (too wide spacing), yield reduction can occur due to in efficient utilization of the growth factors. Normally, as population increases yield also increases proportionally. After, it reached a certain level the yield declines.

Accordingly, the experiment was conducted to determine the effect of inter and intra row spacing on yield and yield components of a kabuli type chickpea variety Habru . A factorial experiment was conducted in RCBD in three replication with 4 inter row spacing, i.e. 20 cm, 30 cm, 40 cm and 50 cm and three intra row spacing of 5 cm, 10 cm, and 15 cm.

Days to 50 % flowering was highly significantly affected by inter row spacing but not significantly affected by intra row spacing. Row spacing of 50 cm was earlier (49.78 days) while row spacing 20 cm took the longest number of days to flower (51.56 days). There was also a slight variation regarding the intra-row spacing, 5cm intra row spacing took slightly longer days (50.54) than the others and 15 cm intra row spacing took the least days to 50% flowering (50.42) days). Days to physiological maturity increased with decreased inter row spacing from 101.61 at 50cm to 104.56 days at 20 cm. Similarly, days to maturity increased from 102.92 to 103.29 days as intra row spacing decreased from 15 cm to 5 cm.Plant heights were significantly affected by inter-row spacing's. The tallest plant recorded at 20 cm inter-row spacing and the shortest at 50cm. plant height also decreased from 13.56cm to 13.04cm as intra-row spacing's increased from 5 to 15. The number of primary branches increased from 3.52 to 6.10 as inter-row spacing increases from 20 cm to 50 cm. similarly it also increases as intra-row spacing's increases. The number of pods plant^{-1}increased with the increase in inter - row spacing at the same level of intra row spacing. The highest number of pods plant^{-1} was obtained with the interaction effect of 50 cm inter- and 15 cm intra- row spacing's. The lowest number of pods plant^{-1} was found in the closest spacing, i.e. 20 cm inter- and 5 cm intra-row spacing's.

Number of seeds per pod was highly significantly affected by inter row spacing and intra row spacing. The highest number of seed per pod (1.23) was obtained at 50 cm inter row spacing and the lowest number of seeds per pod (1.10) was recorded from the 20 cm inter row spacing. On the other hand, from the narrowest (5 cm) intra row spacing the lowest number of seeds per pod (1.12) was recorded and the highest number of seeds per pod (1.19) was recorded at the 15 cm intra row spacing. The main effects of inter - row spacing and intra - row spacing were highly significant on the hundred seed weight. The widest inter row spacing (50 cm) gave the highest hundred seed weight (31.34 g) while the narrower inter row spacing (20 cm) gave the lowest hundred seed weight (29.61 g).

Interaction effects of inter- and intra- row spacing had a highly significant effect on the harvest index. For all of the inter row spacing the harvest index was increased as the intra row spacing increased. The interaction effect of inter row and intra row spacing had also a highly significant effect on the aboveground dry biomass yield. The highest above ground dry biomass (6555kg ha^{-1}) was recorded at 20 cm×5 cm spacing while the lowest number of above ground dry biomass (3896 kg ha^{-1}) was recorded at 50 cm×15 cm spacing. The interaction effect of the two factors was highly significant on grain yield. The interaction of 20 cm inter- and 5 cm intra-row spacing gave the highest grain yield (3036 kg ha^{-1}) .On the other hand, the lowest grain yield (1400 kg ha^{-1}) was recorded with the interaction of 50 cm × 15 cm.

In conclusion, the results from the study indicated that inter row spacing and intra row spacing had a significant influence on the growth, yield components and yield of chickpea. The inter row and intra row spacing of 20 cm×5 cm combinations can be suggested for the area. However, as this is one season experiment at one location, the experiment has to be repeated over locations and seasons with inclusion of more varieties to reach at a more reliable conclusion.

6 Reference

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